Chapter 13
Direct Social Losses - Casualties

13.1 Introduction

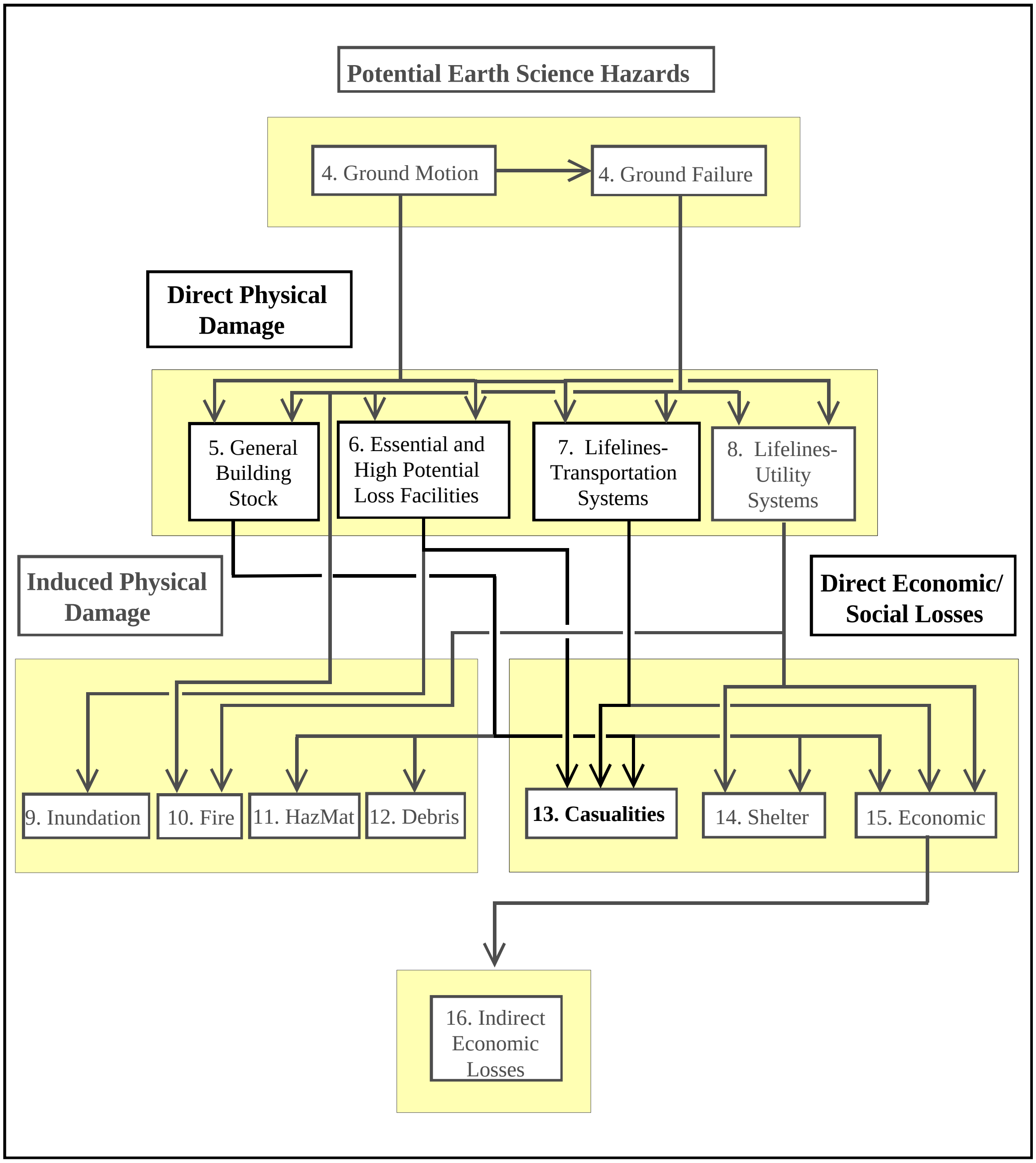
This chapter describes and develops the methodology for the estimation of casualties, describes the form of output, and defines the required input. The methodology is based on the assumption that there is a strong correlation between building damage (both structural and non-structural) and the number and severity of casualties. In smaller earthquakes, non-structural damage will most likely control the casualty estimates. In severe earthquakes where there will be a large number of collapses and partial collapses, there will be a proportionately larger number of fatalities. Data regarding earthquake related injuries is of limited quality and is not available for all building types. Available data often have insufficient information about the type of structure in which the casualties occurred and the casualty generating mechanism. Thus an attempt to develop very sophisticated models based on such data is neither feasible nor reliable. The methodology highlighting the Casualty component is shown in Flowchart 13.1.

13.1.1 Scope

This module provides a methodology for estimating casualties caused only by building damage. Although fire following earthquakes has been the cause of significant casualties (notably in the fire storm following the 1923 Kanto, Japan, earthquake), such cases have involved the combination of a number of conditions that are of low probability of occurrence in U.S. earthquakes. More typical is the catastrophic Oakland Hills fire of 1990, in which over 2000 residences were destroyed; yet casualties were low.

Similarly, there is the possibility of a large number of casualties due to sudden failure of a critical dam, or a massive release of toxic substances. If the particular characteristics of the study region give the user cause for concern about the possibility of casualties from fire, dam failure, or hazardous materials, it would be advisable to initiate specific studies directed towards the problem.

The scope of this module is to provide a simple and consistent framework for earthquake casualty estimation and formats for data collection and data sharing across the disciplines that are involved in casualty estimation. Many recognized relevant issues in casualty estimation such as occupancy potential, collapse and non-collapse vulnerability of the building stock, time of the earthquake occurrence, and spatial distribution of the parameters, are included in the methodology. The methodology is flexible enough to handle:



Flowchart 13.1: Direct Social Loss (Casualties) Relationship to other Components of the Earthquake Loss Estimation Methodology

- Domestic US casualty statistics
- Statistics derived from interpretation of worldwide casualty data
- Multidisciplinary input from professionals involved in earthquake casualty estimation

Data formats are flexible enough to handle currently available data, to re-evaluate previously collected data, and to accept new data as they become available.

13.1.2 Form of Casualty Estimate

The output from the module consists of a casualty breakdown by injury severity level, defined by a four level injury severity scale (Durkin and Thiel, 1991; Coburn, 1992; Cheu, 1994). Casualties are calculated at the census tract level. The output is at the census tract level and aggregated to the study region. Table 13.1 defines the injury classification scale used in the methodology.

Table 13.1: Injury Classification Scale

Injury Severity Level	Injury Description
Severity 1	Injuries requiring basic medical aid without requiring hospitalization
Severity 2	Injuries requiring a greater degree of medical care and hospitalization, but not expected to progress to a life threatening status
Severity 3	Injuries that pose an immediate life threatening condition if not treated adequately and expeditiously. The majority of these injuries are the result of structural collapse and subsequent entrapment or impairment of the occupants.
Severity 4	Instantaneously killed or mortally injured

Other, more elaborate casualty scales exist. They are based on quantifiable medical parameters such as medical injury severity scores, coded physiologic variables, etc. The selected four-level injury scale represents an achievable compromise between the demands of the medical community (in order to plan their response), and the ability of engineering community to provide the required data. For example, medical professionals would like to have the classification in terms of "Injuries/Illnesses" to account for worsened medical conditions caused by an earthquake (e.g., heart attack). However, currently available casualty assessment methodologies do not allow for a finer resolution in the casualty scale definition.

13.1.3 Input Requirements

There are three types of input data for the casualty module:

- Data defined by user
- Data supplied by other modules
- Data specific to the casualty module

<u>Data Defined by User</u>

The methodology provides information necessary to produce casualty estimates for three times of day. The following time options are provided:

- Earthquake striking at 2:00 a.m. (night time)
- Earthquake striking at 2:00 p.m. (day time)
- Earthquake striking at 5:00 p.m. (commute time)

These scenarios are expected to generate the highest casualties for the population at home, the population at work/school and the population during rush hour, respectively.

<u>Data Supplied by Other Modules</u>

The other modules provide the population distribution data, inventory (building stock distribution) data, and damage state probabilities. These data are provided at the census tract level. The values provided as defaults are best estimates made from available data. However, the user may modify the default database on the availability of improved information.

Population Distribution Data

The population for each census tract is distributed into four basic groups:

- Residential population
- Commercial population
- Industrial population
- Commuting population

The default population distribution is calculated for the three times of day for each census tract. Table 13.2 provides the relationships used to determine the default distribution. The population distribution was based on Census data and Dun and Bradstreet data and has an inherent error associated with the distribution. If the user has a better understanding about the distribution of the working/school population among census tracts, the default information should be modified to reflect the improved knowledge.

The commuting population is defined as the number of people expected on the roadways during the commuting time. In this methodology, the only roadway casualties estimated are those incurred from bridge/overpass damage. This requires the user to estimate the number of people located on or under bridges during the seismic event. The methodology provides for a user-defined commuter distribution factor, CDF that corresponds to the percentage of the commuting population located on or under bridges. The number of people on or under bridges in a census tract is then computed as follows.

$$NBRDG = CDF * COMM \tag{13-1}$$

where:

NBRDG	Number of people on or under bridges in the census tract
CDF	Percent of commuters on or under bridges in census tract (Commuter Distribution Factor)
COMM	Number of commuters in census tract

Table 13.2: Default Relationships for Estimating Population Distribution

Distribution of People in Census Tract			
Basic Group	**2:00 a.m.**	**2:00 p.m.**	**5:00 p.m.**
Residential	0.99(NRES)	0.80(DRES)	0.95(DRES)
Commercial	0.02(COMW)	0.98(COMW) + 0.15(DRES) + 0.80(AGE_16)	0.50(COMW)
Industrial	0.10(INDW)	0.80(INDW)	0.50(INDW)
Commuting	0.01(POP)	0.05(POP)	0.05(DRES) + 1.0(COMM)

where:

POP	is the census tract population taken from census data
DRES	is the daytime residential population inferred from census data
NRES	is the nighttime residential population inferred from census data
COMM	is the number of people commuting inferred from census data
COMW	is the number of people employed in the commercial sector
INDW	is the number of people employed in the industrial sector.
AGE_16	is the number of people 16 years of age and under inferred from census data (used as a proxy for the portion of population located in schools)

The User's Manual will provide the user with guidance on how to determine an appropriate value for CDF. The methodology defaults the CDF to assumed values of 0.05 during the day and night time and 0.10 for the commuting time. Local data on the percentage of commuters on or under highway bridges would provide greater accuracy.

General Occupancy to Model Building Type Mapping

The model uses the relationship between the general occupancy classes and the model building type that is calculated by combining the following relationships.

- Specific Occupancy to Model Building Type Relationship
- General Occupancy to Specific Occupancy Relationship

Damage State Probabilities

The casualty model uses the four structural damage states computed by the other modules: slight, moderate, extensive, and complete. For each census tract and each building type and bridge type, the probabilities of the structure being in each of the four damage states is provided by the software.

Data Specific to The Casualty Module

This module limits itself to the estimation of casualties that would be caused by damage to buildings and bridges. Excluded are casualties or health effects not due to immediate physical impact, such as heart attacks, psychological effects, or injuries suffered during post-earthquake clean-up or construction activities. Exterior casualties caused from collapsing masonry parapets or pieces of bearing walls or from falling signs and other appendages are also excluded. The casualty rates used in the methodology are relatively uniform across building types for a given damage level, with differentiation to account for types of construction that pose higher-than-average hazards at moderate damage levels (e.g., falling of pieces of unreinforced masonry) or at severe levels (e.g., complete collapse of heavy concrete construction as compared to wood frame construction). Rates used in the ATC-13 method were evaluated and revised based on comparison with a limited amount of historical data. For the Northridge Earthquake, the casualties estimated by the methodology are a reasonably representation of the actual numbers observed.

The following default casualty rates are defined by the methodology.

- Casualty rates by model building type for slight structural damage
- Casualty rates by model building type for moderate structural damage
- Casualty rates by model building type for extensive structural damage
- Casualty rates by model building type for complete structural damage without structural collapse
- Casualty rates by model building type for complete structural damage with structural collapse
- Collapse rates by model building type for complete structural damage state.
- Casualty rates for bridges with complete structural damage

It should be noted that only a portion of the buildings in the complete damage state are considered to be collapsed. The relevant percentages for each model building type are given in Chapter 5. Tables 13.3 through 13.9 define the values for the default casualty module data.

Table 13.3: Casualty Rates by Model Building Type for Slight Structural Damage

#	Building Type	Casualty Severity Level			
		Severity 1 (%)	Severity 2 (%)	Severity 3 (%)	Severity 4 (%)
1	W1	0.05	0.005	0	0
2	W2	0.05	0.005	0	0
3	S1L	0.05	0.005	0	0
4	S1M	0.05	0.005	0	0
5	S1H	0.05	0.005	0	0
6	S2L	0.05	0.005	0	0
7	S2M	0.05	0.005	0	0
8	S2H	0.05	0.005	0	0
9	S3	0.05	0.005	0	0
10	S4L	0.05	0.005	0	0
11	S4M	0.05	0.005	0	0
12	S4H	0.05	0.005	0	0
13	S5L	0.05	0.005	0	0
14	S5M	0.05	0.005	0	0
15	S5H	0.05	0.005	0	0
16	C1L	0.05	0.005	0	0
17	C1M	0.05	0.005	0	0
18	C1H	0.05	0.005	0	0
19	C2L	0.05	0.005	0	0
20	C2M	0.05	0.005	0	0
21	C2H	0.05	0.005	0	0
22	C3L	0.05	0.005	0	0
23	C3M	0.05	0.005	0	0
24	C3H	0.05	0.005	0	0
25	PC1	0.05	0.005	0	0
26	PC2L	0.05	0.005	0	0
27	PC2M	0.05	0.005	0	0
28	PC2H	0.05	0.005	0	0
29	RM1L	0.05	0.005	0	0
30	RM1M	0.05	0.005	0	0
31	RM2L	0.05	0.005	0	0
32	RM2M	0.05	0.005	0	0
33	RM2H	0.05	0.005	0	0
34	URML	0.05	0.005	0	0
35	URMM	0.05	0.005	0	0
36	MH	0.05	0.005	0	0

Table 13.4: Casualty Rates by Model Building Type for Moderate Structural Damage

#	Building Type	Casualty Severity Level			
		Severity 1 (%)	Severity 2 (%)	Severity 3 (%)	Severity 4 (%)
1	W1	0.2	0.02	0	0
2	W2	0.2	0.02	0	0
3	S1L	0.2	0.02	0	0
4	S1M	0.2	0.02	0	0
5	S1H	0.2	0.02	0	0
6	S2L	0.2	0.02	0	0
7	S2M	0.2	0.02	0	0
8	S2H	0.2	0.02	0	0
9	S3	0.2	0.02	0	0
10	S4L	0.2	0.02	0	0
11	S4M	0.2	0.02	0	0
12	S4H	0.2	0.02	0	0
13	S5L	0.2	0.02	0	0
14	S5M	0.2	0.02	0	0
15	S5H	0.2	0.02	0	0
16	C1L	0.2	0.02	0	0
17	C1M	0.2	0.02	0	0
18	C1H	0.2	0.02	0	0
19	C2L	0.2	0.02	0	0
20	C2M	0.2	0.02	0	0
21	C2H	0.2	0.02	0	0
22	C3L	0.2	0.02	0	0
23	C3M	0.2	0.02	0	0
24	C3H	0.2	0.02	0	0
25	PC1	0.2	0.02	0	0
26	PC2L	0.2	0.02	0	0
27	PC2M	0.2	0.02	0	0
28	PC2H	0.2	0.02	0	0
29	RM1L	0.2	0.02	0	0
30	RM1M	0.2	0.02	0	0
31	RM2L	0.2	0.02	0	0
32	RM2M	0.2	0.02	0	0
33	RM2H	0.2	0.02	0	0
34	URML	0.4	0.04	0	0
35	URMM	0.4	0.04	0	0
36	MH	0.2	0.02	0	0

Table 13.5: Casualty Rates by Model Building Type for Extensive Structural Damage

#	Building Type	Casualty Severity Level			
		Severity 1 (%)	Severity 2 (%)	Severity 3 (%)	Severity 4 (%)
1	W1	1	0.1	0.001	0.001
2	W2	1	0.1	0.001	0.001
3	S1L	1	0.1	0.001	0.001
4	S1M	1	0.1	0.001	0.001
5	S1H	1	0.1	0.001	0.001
6	S2L	1	0.1	0.001	0.001
7	S2M	1	0.1	0.001	0.001
8	S2H	1	0.1	0.001	0.001
9	S3	1	0.1	0.001	0.001
10	S4L	1	0.1	0.001	0.001
11	S4M	1	0.1	0.001	0.001
12	S4H	1	0.1	0.001	0.001
13	S5L	1	0.1	0.001	0.001
14	S5M	1	0.1	0.001	0.001
15	S5H	1	0.1	0.001	0.001
16	C1L	1	0.1	0.001	0.001
17	C1M	1	0.1	0.001	0.001
18	C1H	1	0.1	0.001	0.001
19	C2L	1	0.1	0.001	0.001
20	C2M	1	0.1	0.001	0.001
21	C2H	1	0.1	0.001	0.001
22	C3L	1	0.1	0.001	0.001
23	C3M	1	0.1	0.001	0.001
24	C3H	1	0.1	0.001	0.001
25	PC1	1	0.1	0.001	0.001
26	PC2L	1	0.1	0.001	0.001
27	PC2M	1	0.1	0.001	0.001
28	PC2H	1	0.1	0.001	0.001
29	RM1L	1	0.1	0.001	0.001
30	RM1M	1	0.1	0.001	0.001
31	RM2L	1	0.1	0.001	0.001
32	RM2M	1	0.1	0.001	0.001
33	RM2H	1	0.1	0.001	0.001
34	URML	2	0.2	0.002	0.002
35	URMM	2	0.2	0.002	0.002
36	MH	1	0.1	0.001	0.001

Table 13.6: Casualty Rates by Model Building Type for Complete Structural Damage (No Collapse)

#	Building Type	Casualty Severity Level			
		Severity 1 (%)	Severity 2 (%)	Severity 3 (%)	Severity 4 (%)
1	W1	5	1	0.01	0.01
2	W2	5	1	0.01	0.01
3	S1L	5	1	0.01	0.01
4	S1M	5	1	0.01	0.01
5	S1H	5	1	0.01	0.01
6	S2L	5	1	0.01	0.01
7	S2M	5	1	0.01	0.01
8	S2H	5	1	0.01	0.01
9	S3	5	1	0.01	0.01
10	S4L	5	1	0.01	0.01
11	S4M	5	1	0.01	0.01
12	S4H	5	1	0.01	0.01
13	S5L	5	1	0.01	0.01
14	S5M	5	1	0.01	0.01
15	S5H	5	1	0.01	0.01
16	C1L	5	1	0.01	0.01
17	C1M	5	1	0.01	0.01
18	C1H	5	1	0.01	0.01
19	C2L	5	1	0.01	0.01
20	C2M	5	1	0.01	0.01
21	C2H	5	1	0.01	0.01
22	C3L	5	1	0.01	0.01
23	C3M	5	1	0.01	0.01
24	C3H	5	1	0.01	0.01
25	PC1	5	1	0.01	0.01
26	PC2L	5	1	0.01	0.01
27	PC2M	5	1	0.01	0.01
28	PC2H	5	1	0.01	0.01
29	RM1L	5	1	0.01	0.01
30	RM1M	5	1	0.01	0.01
31	RM2L	5	1	0.01	0.01
32	RM2M	5	1	0.01	0.01
33	RM2H	5	1	0.01	0.01
34	URML	10	2	0.02	0.02
35	URMM	10	2	0.02	0.02
36	MH	5	1	0.01	0.01

Table 13.7: Casualty Rates by Model Building Type for Complete Structural Damage (With Collapse)

#	Building Type	Casualty Severity Level			
		Severity 1 (%)	Severity 2 (%)	Severity 3 (%)	Severity 4 (%)
1	W1	50	10	1	1
2	W2	50	10	2	2
3	S1L	50	10	2	2
4	S1M	50	10	2	2
5	S1H	50	10	2	2
6	S2L	50	10	2	2
7	S2M	50	10	2	2
8	S2H	50	10	2	2
9	S3	50	10	1	1
10	S4L	50	10	2	2
11	S4M	50	10	2	2
12	S4H	50	10	2	2
13	S5L	50	10	2	2
14	S5M	50	10	2	2
15	S5H	50	10	2	2
16	C1L	50	10	2	2
17	C1M	50	10	2	2
18	C1H	50	10	2	2
19	C2L	50	10	2	2
20	C2M	50	10	2	2
21	C2H	50	10	2	2
22	C3L	50	10	2	2
23	C3M	50	10	2	2
24	C3H	50	10	2	2
25	PC1	50	10	2	2
26	PC2L	50	10	2	2
27	PC2M	50	10	2	2
28	PC2H	50	10	2	2
29	RM1L	50	10	2	2
30	RM1M	50	10	2	2
31	RM2L	50	10	2	2
32	RM2M	50	10	2	2
33	RM2H	50	10	2	2
34	URML	50	10	2	2
35	URMM	50	10	2	2
36	MH	50	10	1	1

Table 13.8: Collapse Rates by Model Building Type for Complete Structural Damage

	Model Building Type	Probability of Collapse Given a Complete Damage State*
1	W1	5%
2	W2	5%
3	S1L	20%
4	S1M	15%
5	S1H	10%
6	S2L	20%
7	S2M	15%
8	S2H	10%
9	S3	25%
10	S4L	20%
11	S4M	15%
12	S4H	10%
13	S5L	25%
14	S5M	20%
15	S5H	15%
16	C1L	20%
17	C1M	15%
18	C1H	10%
19	C2L	20%
20	C2M	15%
21	C2H	10%
22	C3L	25%
23	C3M	20%
24	C3H	15%
25	PC1	25%
26	PC2L	25%
27	PC2M	20%
28	PC2H	15%
29	RM1L	20%
30	RM1M	15%
31	RM2L	20%
32	RM2M	15%
33	RM2H	10%
34	URML	25%
35	URMM	25%
36	MH	5%

* See Chapter 5 for derivation of these values

13.2 Description of Methodology

The casualty model is complementary to the concepts put forward by some other models (Coburn and Spence, 1992; Murkami, 1992, Shiono, et. al., 1991). The Coburn and Spence model uses the same four-level injury severity scale (light injuries, hospitalized injuries, life threatening injuries and deaths) and underlying concepts associated with building collapse. However, it is not in event tree format and does not account for non-collapse (damage) related casualties, nor does it account for the population not indoors at the time of earthquake. The Murkami model is an event tree model that includes only fatalities caused by collapsed buildings and does not account for injuries. Shiono's model is similar to the other two models and only estimated fatalities.

The methodology takes into account a wider range of causal relationships in the casualty modeling. It is an extension of the model proposed by Stojanovski and Dong (1994).

13.2.1 Earthquake Casualty Model

Casualties caused by a postulated earthquake can be modeled by developing a tree of events leading to their occurrence. As with any event tree, the earthquake-related casualty event tree begins with an initiating event (earthquake scenario) and follows the possible course of events leading to loss of life or injuries. The logic of its construction is forward (inductive). At each node of the tree, the (node branching) question is: What happens if the preceding event leading to the node occurs? The answers to this question are the branches of the tree. The number of branches from any node is equal to the number of answers selected as relevant to the node branching question. Each branch of the tree is assigned a probability of occurrence. For earthquake related casualties, some of these probabilities cannot be obtained as long run relative frequencies because earthquakes (the initiating events) are rare events and long run frequencies are not available. One possibility is to infer them from the available data statistics, combined with expert opinion, classical statistical and Bayesian inference. Therefore, the assigned probabilities in this case are subjective, and the probability itself may be subjectively defined as degree of belief that an event will occur.

For example, to choose one severity of casualty, the expected number of occupants killed in a building during a given earthquake could be simulated with an event tree, as shown in Figure 13.1. For illustrative purposes it contains as events of interest "occupants killed", only. Evaluation of the branching probabilities constitutes the main effort in the earthquake casualty modeling. Assuming that all the branching probabilities are known or inferred, the probability of an occupant being killed (P_{killed}) is given as follows.

$$P_{killed} = P_A * P_E + P_B * P_F + P_C * P_G + P_D * (P_H * P_J + P_I * P_K) \qquad (13\text{-}2)$$

By introducing the substitutions

$$P_{killed \mid collapse} = P_D * P_I * P_K \qquad (13\text{-}3)$$

and

$$P_{killed \mid no\text{-}collapse} = P_A * P_E + P_B * P_F + P_C * P_G + P_D * P_H * P_J \qquad (13\text{-}4)$$

Equation (13-1) could be simply re-written as:

$$P_{killed} = P_{killed \mid collapse} + P_{killed \mid no\text{-}collapse} \qquad (13\text{-}5)$$

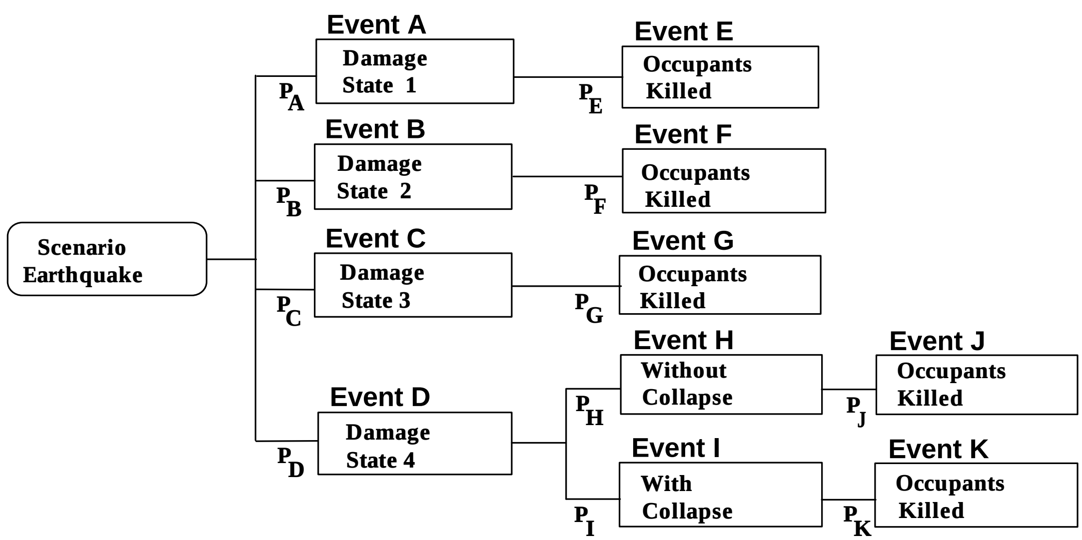


Figure 13.1: Casualty Event Tree Modeling.

The first term in equation 13-5 is associated with the building collapse. The second term is associated with the level of non-collapse damage the building sustains during the earthquake. Records from past earthquakes show that for different regions in the world with different kind of construction there are different threshold intensities at which the first term begins to dominate. For intensities below that shaking level, casualties are primarily damage or non-collapse related. For intensities above that level, the collapse, often of only a few structures, may control the casualty pattern.

The expected number of occupants killed ($EN_{occupants\ killed}$) is a product of the number of occupants of the building at the time of earthquake ($N_{occupants}$) and the probability of an occupant being killed (P_{killed}).

$$EN_{occupants\ killed} = N_{occupants} * P_{killed} \qquad (13\text{-}6)$$

The general earthquake related casualty estimation problem is more complex than the presented example. Problems of similar or higher complexity have been successfully tackled by event tree or fault tree simulation in the field of industrial safety and industrial reliability since the early 1960s.

Figure 13.2 presents a more complete earthquake related casualty event tree, which is used in the methodology. The branching probabilities are not shown in the figure in order to make the model presentation simpler. The events are represented with rectangular boxes. A short event or state description is given in the boxes.

The symbol "<" attached to the event box means that branching out from that node is identical to branching for the same category event (obviously, the appropriate probabilities would be different).

The event tree in Figure 13.2 is conceptual. It integrates several different event trees into one (light injuries, hospitalized injuries, life threatening injuries and deaths) for different types (residential, commercial, industrial, commuting). Casualty rates are different depending on the preceding causal events: damage state, collapse, population indoors, etc.

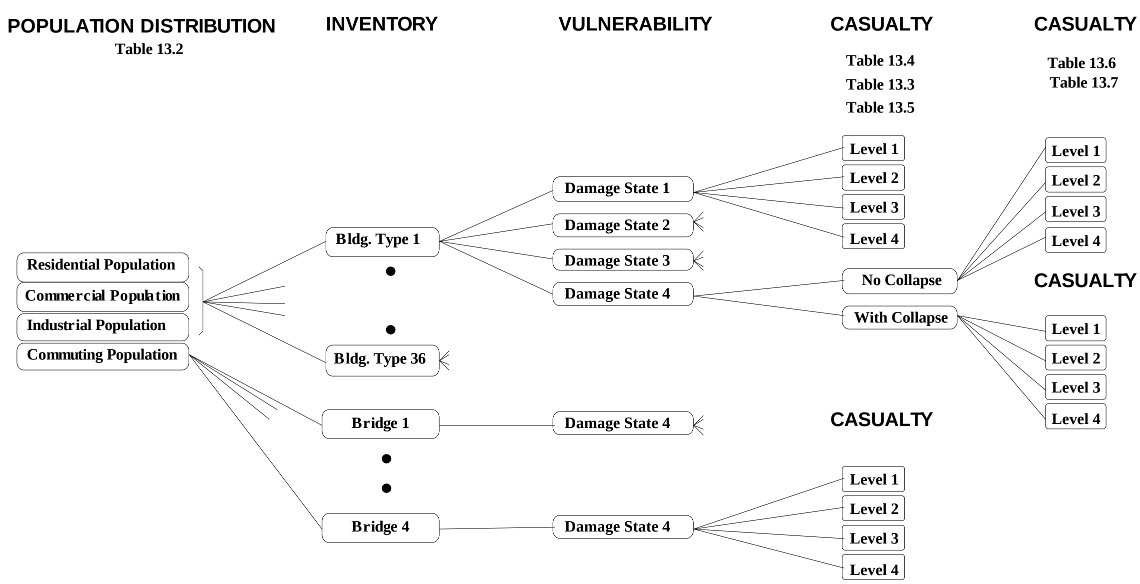


Figure 13.2: Casualty Event Tree Model.

The model is capable of using the best available non-region-specific casualty rates. This capability is attributed to the property of the event tree analysis: that all branching probabilities are conditional upon the occurrence of the node associated event. If average worldwide casualty statistics or data from one or few other countries are to be used for collapse-related casualty modeling in the United States, special attention must be given to the relationship between the U.S. structural types and the structural types represented by these other data sets. Also, appropriate mapping between injury classification scales must be established. Finally, it is possible that differing levels of earthquake preparedness, such as the effectiveness of the emergency health system, and the training of the public in personal protective measures, such as "duck and cover", might cause U.S. casualty rates to differ from those overseas, but this is unlikely to be a significant factor in cases of collapse, and at the present no data is available on these kinds of issues.

13.2.2 Alternative Estimation of Casualty Rates

In earthquakes that don't cause significant collapse, a significant portion of the casualty total is caused to nonstructural damage, accidents, medical conditions, etc. which make the casualty contributing factors difficult to predict and quantify. Occupant contact with nonstructural elements and building contents is a major source of minor injuries in this case, with a much smaller proportion of serious injuries and deaths. Occupant actions may also contribute to injuries, e.g., while attempting to take evasive action (Durkin, 1992).

In the absence of adequate U.S.-specific casualty data (as a consequence of structural collapse), international data on the casualty rates for specific structural types may be used. This means that U.S. construction practices, design and construction quality would have to be reflected in the appropriate region-specific fragility curves. Published data on collapse-related casualty rates is limited. Noji (Noji, E.K., "Epidemic Studies from the 1988 Armenia Earthquake: Implications for Casualty Modeling", Workshop on Earthquake Casualty Modeling, Asilomar, California, December 4-6, 1990) provided this type of data for stone masonry and precast concrete buildings. Murakami (1992) used these rates in a model that simulated the fatalities from the same event. Durkin and Murakami (1989) reported casualty rates for two reinforced concrete buildings collapsed during the 1985 Mexico and 1986 San Salvador earthquakes. Shiono at al. (1991) provided fatality rates after collapse for most common worldwide structural types. Coburn et al. (1992) have summarized approximate casualty rates for masonry and reinforced concrete structures based on worldwide data.

The casualty patterns for people who evacuate collapsed buildings, either before or immediately after the collapse, are more difficult to quantify. Statistical data on these casualty patterns is lacking, since in most post-earthquake reconnaissance efforts these injuries are not distinguished from other causes of injuries. In some cases, the lighter injuries may not be reported. An assumption that those who manage to evacuate are neither killed nor receive life threatening injuries, may be applied. Often it is assumed that 50% of the occupants of the first floor manage to evacuate.

Experience in a number of earthquakes overseas and in the United States has shown that a number of casualties occur outside buildings due to falling materials. In the United States these casualties have been caused primarily by falling unreinforced masonry, which may cause damage to an adjoining building and result in casualties, or, fall directly on people outside the building. It is suggested that planners should investigate their building stock, particularly with respect to a high intensity of URM buildings located where damage might be caused to other buildings or where people congregate, and consider adding some casualties to the estimates if potential dangerous situations are revealed. To accomplish this, the number of people would be on sidewalks or similar exterior areas must be estimated. This sum must not be double-counted with the calculation of building occupants.

13.2.3 Casualty Rates Resulting from Bridge Collapse

Casualty rates are provided in Table 13.9 (Casualty Rates for Complete Structural damage) for bridges that have been completely damaged. Lack of data did not allow similar inferences for other damage states.

Single Span Bridges

The only reference which reports on many aspects of a single span bridge collapse is "Loma Prieta Earthquake October 17, 1989; I-80 San Francisco - Oakland Bay Bridge, Closure Span Collapse", published by the Department of California Highway Patrol in 1990. This document systematically reports most of the facts related to the collapse of the bridge.

During the Loma Prieta earthquake the closure spans collapsed. The only fatality was recorded approximately half an hour after the event when a car fell into the gap created by the collapse.

Table 13.9: Casualty Rates for Bridges (Complete Structural Damage)

#	Building Type	Casualty Severity Level			
		Severity 1 (%)	Severity 2 (%)	Severity 3 (%)	Severity 4 (%)
B1	Major Bridge	17	20	37	7
B2	Continuous Bridge	17	20	37	7
B3	Single Span Bridge	5	25	20	5

Major and Continuous Bridges

The only reference which reports on many aspects of a continuous (major) bridge collapse is "Loma Prieta Earthquake October 17, 1989; I-880 Cypress Street Viaduct Structure Collapse", published by the Department of California Highway Patrol in 1990. This reference systematically reports most of the facts related to the collapse of the bridge.

Most of the injuries and fatalities occurred on the lower northbound deck as a consequence of the collapse of the upper deck onto the lower deck. A significant portion of injuries and fatalities also occurred among the people driving on the upper southbound deck. A small portion of casualties resulted from vehicles on the surface streets adjacent to the collapsed structure.

For casualty rates for major and continuous bridges, casualty statistics on the upper deck of the Cypress Viaduct and on the adjacent surface streets have been used. Casualties associated with the vehicles on the lower deck are not considered representative because double deck bridges and freeways are not common.

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